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QUALITY AND CONDITION CHANGES OF McINTOSH APPLES STORED IN CONTROLLED ATMOSPHERES

By G. D. BLANPIED[1] and D. H. DEWEY
DEPARTMENT OF HORTICULTURE

CONTROLLED ATMOSPHERE STORAGE McIntosh apples are usually marketed after the regular cold-storage supply is depleted. However, there is occasionally a desire to market them earlier. CA storage will prolong the life of McIntosh[2], but little is known about the quality of the fruit during the earlier portion of the marketing season. Studies were made of quality and condition changes of this variety stored in regular air and in controlled atmospheres during the 1957-58 and 1958-59 seasons.

The results should be useful to apple handlers in determining when quality differences would justify earlier openings of CA rooms, and in anticipating normal changes in fruit condition once apples have been removed from storage.

Apples used for study were harvested from trees in commercial blocks of the Sparta and Belding fruit areas and on the Michigan State University experimental farm at East Lansing. Samples were stored in air at 32-33° F. (Check) and in an atmosphere of 3 percent oxygen and 5 percent carbon dioxide at 38° F. (CA) during the 1957-58 and 1958-59 seasons.

Flesh Firmness

Changes in flesh firmness of the apples at intervals during the 1957-58 storage period are shown in Fig. 1—Part A. During the first half of the storage season, the check apples were firmer than the CA

[1]Present address: Pomology Department, Cornell University, Ithaca, New York.

[2]Van Doren, A. (1939). Physiological studies with McIntosh apples in modified atmosphere cold storage. Proc. Amer. Soc. Hort. Sci. 37: 453-458.
Smock, R. M. (1942). Influence of controlled atmosphere storage on respiration of McIntosh apples. Bot. Gaz. 104: 178-184.
Phillips, W. R. and P. A. Poapst (1952). Storage of apples. Canada Dept. of Agr. Publ. 776, 42 pp. (Rev.).

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apples. At the mid-point of the storage period, however, firmness of the CA apples levelled off slightly above 9.0 pounds while the checks continued to decline in pressure to 8.5 pounds before levelling off.

A similar trend of flesh softening was observed for the 1958-59 storage season (Fig. 2). The CA fruit, however, was firmer than the check fruit at three months. No information on the rate of flesh softening between harvest and three months was obtained.

Changes in flesh firmness of CA and check apples after seven days at 75° F., following removal from storage in the 1957-58 season, are shown in Part B of Fig. 1. The pattern noted for softening after seven

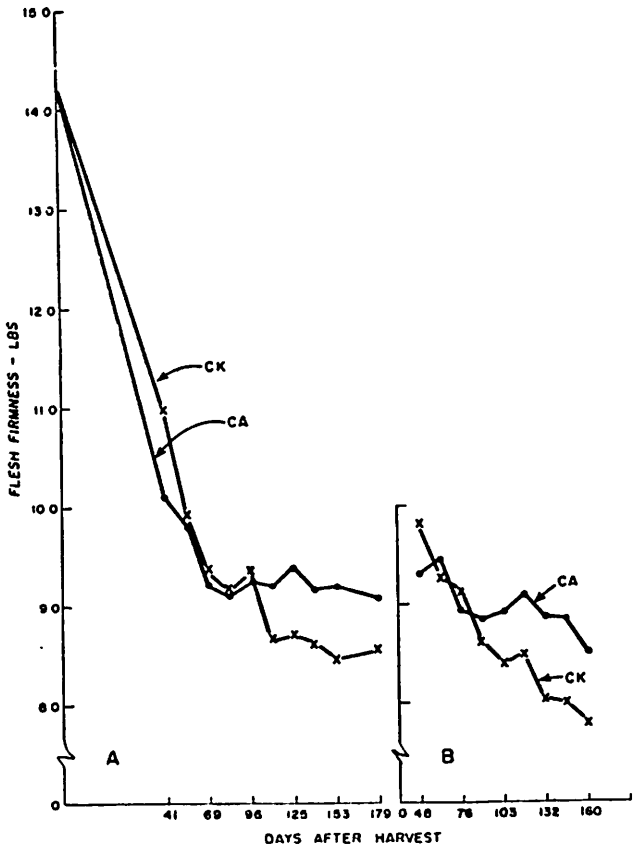
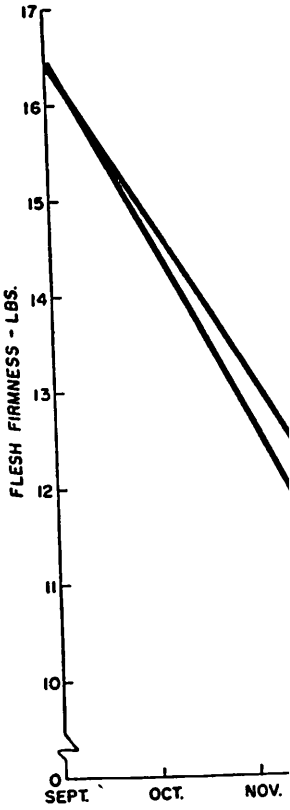


Fig. 1. Flesh firmness of McIntosh apples upon removal from controlled atmosphere (CA) and regular storage (Ck) during the 1957-58 season. A, after one day at 75° F.; B, after seven days at 75° F.



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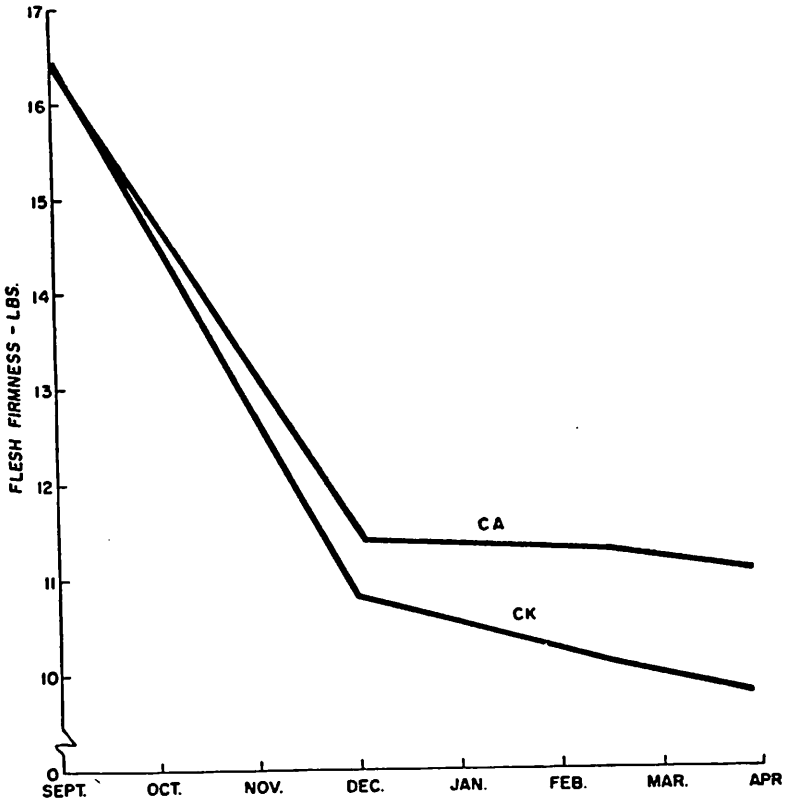
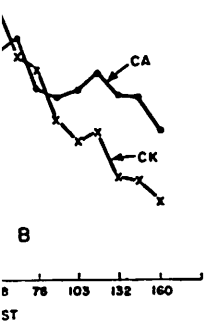


Fig. 2. Flesh firmness of McIntosh apples removed from controlled atmosphere (CA) and regular (Ck) storages in early December, February and late March (1958-59 season).



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days for both CA and check apples was similar to the pattern for the various times of removal from storage. The amount of flesh softening at 75° F. was similar, being 0.4 pounds for the CA apples and 0.6 pounds for the check apples.

Apples obtained from four orchards were removed from storages in March, 1959. Samples were tested for firmness after one and seven days at 75° F. and after eight weeks of additional storage in regular air at 33° F. (Table 1). The CA apples were firmer than the check apples at all sampling dates. Average softening during six days at 75° F. was similar for the two storage treatments; however, softening was erratic according to orchard source of the fruit. It ranged from 0.2 to 1.2 pounds for CA fruit, and from 0.4 to 1.3 pounds for check

fruit. The CA apples softened 0.4 pounds during the additional eight weeks of storage at 33° F. in regular air while the check apples had an average loss of 0.1.

The present study shows that apples stored in CA to January and later had firmer flesh than apples stored for the same periods in regular air. The rapid softening noted for the CA apples in the early period of storage may have resulted from the high storage temperature, and in particular, during the initial two-week period required to reduce the oxygen level to 3 percent. Temperatures below 38° F. are not used in CA storage of McIntosh apples because they tend to increase the incidence of carbon dioxide injury and brown core.[3]

Since softening rates of the fruit differed only during storage, any advantage in flesh firmness expected for CA apples over apples from regular storage must be gained prior to removing them from the sealed storage.

TABLE 1—Flesh firmness(a) of McIntosh apples from four orchards stored in controlled atmospheres (CA) and regular air (Ck) to March.

Orchard	Before storage	Storage plus 1 day at 75° F.		Storage plus 7 days at 75° F.		Loss during 6 days at 75° F.		Storage plus 8 weeks at 33° F.	
		Ck	CA	Ck	CA	Ck	CA	Ck	CA
A	16.5	8.8	11.1	8.4	9.9	0.4	1.2	8.9	9.9
B	14.9	8.3	9.5	7.0	8.6	1.3	0.9	8.2	9.2
C	15.1	8.6	9.6	7.5	8.6	1.1	1.0	8.2	9.2
D	16.0	9.1	9.3	8.1	9.1	1.0	0.2	9.0	9.6
Average.....	15.6	8.7	9.9	7.8	9.1	1.0	0.8	8.6	9.5

(a) Measured in pounds by a Magness-Taylor tester with a 7/16 inch tip.

Panel Evaluations

A panel of five to six persons, experienced in evaluating fruit quality, judged appearance, texture, flavor and ripeness characteristics of apples removed from CA and regular storage at two-week intervals during the 1957-58 season. High quality was given a rating value of 5; poor quality, namely, unmarketable appearance, mealy texture, lacking in flavor and overripe, was rated 0, while gradations of intermediate quality were rated 1, 2, 3 or 4.

The panel was unable to note quality differences consistently

[3]Op. cit., footnote 2.

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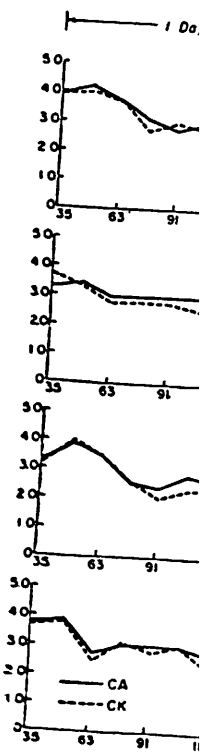

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Loss during 6 days at 75° F.		Storage plus 8 weeks at 33° F.	
Ck	CA	Ck	CA
0.4	1.2	8.9	9.9
1.3	0.9	8.2	9.2
1.1	1.0	8.2	9.2
1.0	0.2	9.0	9.6
1.0	0.8	8.6	9.5

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until the mid-point of the storage season (Fig. 3). There was little subsequent decline in quality of the CA fruit while check fruit continued to deteriorate through the remainder of the storage season. The differences due to storage treatment at one and seven days after removal from storage were similar. At the end of the storage season, the CA fruit was ripe in taste and appearance, melting in texture, and sweet in flavor.

Panel ratings for apples from the four orchards upon storage to March are given in Table 2. Although apples from a given orchard consistently kept better in controlled atmospheres than in regular air, the degree of superiority of the CA apples was variable. For instance, the panel gave a 0.6 point difference for CA and check apples from Orchard C, and 1.4 points difference for the apples of Orchard B. Also, the check apples of Orchard D were rated higher in quality than

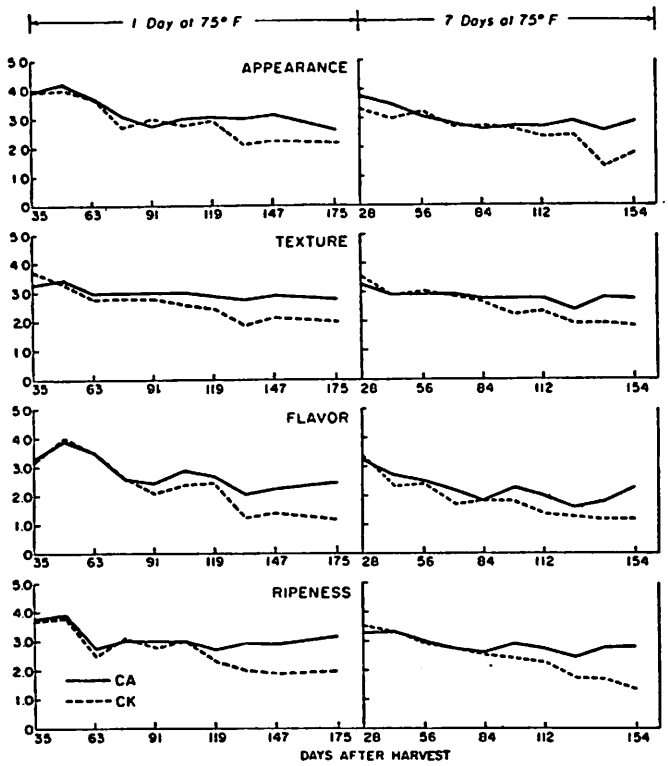

Fig. 3. Quality ratings (0 to 5.0) of McIntosh apples after removal from controlled atmosphere (CA) and regular (Ck) storages during the 1957-58 season.

CA apples from Orchard C. It is apparent that factors other than storage method are often important in determining the final quality of stored fruit.

TABLE 2—Quality ratings of McIntosh apples after four days at 75° F. following storage to April in controlled atmospheres (CA) and regular air (Ck)

Orchard	Texture			Flavor			Ripeness			Average		
	CA	Ck	Diff.	CA	Ck	Diff.	CA	Ck	Diff.	CA	Ck	Diff.
A	3.2	2.6	0.6	3.4	2.9	0.5	3.8	3.0	0.8	3.5	2.8	0.7
B	3.0	1.8	1.2	3.5	1.8	1.7	3.3	2.1	1.2	3.3	1.9	1.4
C	2.1	1.5	0.6	1.8	1.2	0.6	2.1	1.4	0.7	2.0	1.4	0.6
D	3.0	2.6	0.4	3.1	1.9	1.2	2.8	2.4	0.4	3.0	2.3	0.7
Average.....	2.8	2.1	0.7	3.0	2.0	1.0	3.0	2.2	0.8	3.0	2.1	0.9

Skin Toughness

Puncture tests of epidermal tissues of apples confirmed the general observation that CA apples have a tougher skin than apples stored by regular means. Pressure values required to break the skin of apples following storage to March are shown in Table 3. In all instances, the skin of the CA apples was significantly resistant to puncture. Continued storage at 33° F. in regular air for eight weeks tended to reduce resistance of the CA apple skin.

Other Condition Factors

Data concerning other condition factors for apples from the four orchards are given in Table 4. Soluble solid contents of the extracted juice of the apples were not affected by storage treatment. There was a greater amount of skin shrivel of the check apples than on CA apples. This difference was probably due to the lower relative humidity in regular storage. No senescent core browning was found after a holding period of one week at 75° F. in the CA apples, while 20 to 95 percent of the check apples were affected. After two weeks, 16.7 percent of the CA apples showed traces of senescent core browning and 94.7 percent of the check apples were severely affected. The percent of CA and check apples with storage scald increased slightly upon holding so that at two weeks, 97.5 percent of the check apples were

TABLE 3—Skin toughnes storage to March in

Storage treatment and holding period
Magness-Taylor pressur
CA—4 days at 75° F.....
Ck—4 days at 75° F.....
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CA—4 days at 75° F.....
Ck—4 days at 75° F.....
CA—8 weeks at 33° F. plus 1 day at 75° F.....
Ck—8 weeks at 33° F. plus 1 day at 75° F.....

**Significant at 1% level.
*Significant at 5% level.

TABLE 4—Condition of Mc two weeks at 75° F. follo (CA) and regular air (C

Orchard	Storage treatment	Soluble solids (a)	Sk shriv
		1 week (%)	1 we (rati
A	CA	12.0	Slight
	Ck	12.0	Moder
B	CA	10.5	Slight
	Ck	10.5	Mod-S
C	CA	11.5	Slight
	Ck	11.0	Slight
D	CA	11.3	Slight
	Ck	11.3	Modera
Average	CA	11.3	Slight
	Ck	11.2	Modera

(a) Soluble solids at harvest: A—12.5%
(b) Skin shrivel when apple was pressed

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Ripeness			Average		
	Ck	Diff.	CA	Ck	Diff.
	3.0	0.8	3.5	2.8	0.7
	2.1	1.2	3.3	1.9	1.4
	1.4	0.7	2.0	1.4	0.6
	2.4	0.4	3.0	2.3	0.7
	2.2	0.8	3.0	2.1	0.9

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TABLE 3—Skin toughness of McIntosh apples from four orchards after storage to March in controlled atmospheres (CA) and regular air (Ck)

Storage treatment and holding period	Orchard A	Orchard B	Orchard C	Orchard D	Average
Magness-Taylor pressure tester: pounds to break the peeled skin with 5/16" tip					
CA—4 days at 75° F.....	7.2	5.4	5.3	5.4	5.8**
Ck—4 days at 75° F.....	3.9	4.9	4.0	4.5	4.4
Chatillon dynamometer: grams to break intact skin with 0.8 mm. tip					
CA—4 days at 75° F.....	273	263	263	275	269**
Ck—4 days at 75° F.....	208	225	220	239	223
CA—8 weeks at 33° F. plus 1 day at 75° F.....	242	240	229	250	240*
Ck—8 weeks at 33° F. plus 1 day at 75° F.....	207	212	210	225	215

**Significant at 1% level.
*Significant at 5% level.

TABLE 4—Condition of McIntosh apples from four orchards after one and two weeks at 75° F. following storage to March in controlled atmospheres (CA) and regular air (Ck)

Orchard	Storage treatment	Soluble solids (a)	Skin shrivel(b)	Senescent core browning			Storage scald		Mealy breakdown
		1 week (%)	1 week (rating)	1 week (%)	2 weeks (%)	(amount)	1 week (%)	2 weeks (%)	2 weeks (%)
A	CA	12.0	Slight	0.0	8.8	Trace	0.0	0.0	0.0
	Ck	12.0	Moderate	25.0	77.4	Moderate	74.3	95.2	22.6
B	CA	10.5	Slight	0.0	30.4	Trace	2.9	2.2	0.0
	Ck	10.5	Mod-Severe	95.0	100.0	Severe	91.4	100.0	10.9
C	CA	11.5	Slight	0.0	16.7	Trace	17.1	27.0	0.0
	Ck	11.0	Slight	20.0	98.2	Severe	62.9	94.6	37.5
D	CA	11.3	Slight	0.0	10.7	Trace	5.7	3.6	0.0
	Ck	11.3	Moderate	95.0	98.1	Severe	97.1	100.0	5.6
Average	CA	11.3	Slight	0.0	16.7	Trace	6.4	8.2	0.0
	Ck	11.2	Moderate	58.8	94.7	Severe	81.4	97.5	19.2

(a) Soluble solids at harvest: A—12.5%; B—11.5%; C—12.0%; D—12.0%.
(b) Skin shrivel when apple was pressed between the thumb and forefinger.

affected while only 8.2 percent of the CA apples were scalded. No mealy breakdown was observed at this time in CA apples; whereas, 5.6 to 37.5 percent of the check apples showed this disorder.

SUMMARY AND CONCLUSIONS

McIntosh apples stored in controlled atmospheres of 5 percent carbon dioxide and 3 percent oxygen at 38° F. and in regular cold storage at 33° F. were observed for quality and condition changes during and following storage.

Quality differences according to method of storage were not evident until the fruit had been stored for approximately 100 days. The superiority of the CA apples in respect to flesh firmness, texture, flavor, and degree of ripening became more apparent as the storage period lengthened.

Loss of quality after removal from storage was similar for apples from both storage conditions at each removal date. The duration of market or shelf-life of the apples, therefore, was primarily dependent upon the extent of the changes which had already occurred during storage. Pre-storage factors also were important since fruit from different orchards varied in final quality.

Development of senescent core browning, storage scald and mealy breakdown was retarded by controlled atmosphere storage.

Puncture tests showed that the skin of CA apples is tougher than that of apples from ordinary cold storage.